**The design criterion in chemistry internal assessment**

Deciding upon the most suitable strategy for assessing the design criterion is one of the most important decisions for the teacher of IB chemistry. The questions to be considered when implementing a design strategy are as follows:

* How much lesson time is to be allocated to the task?
* How many students are in the teaching group?
* What resources are available for use by the students?
* Will the task stimulate a spirit of inquiry in the students and promote thinking skills in addressing a complex problem?
* Do the students have the prerequisite skills and knowledge base to address the task in a meaningful manner?
* Can the teacher ensure that, when completing the written phase of the investigation outside the classroom, the students work independently?

The answers to these questions will differ according to each school’s environment, but some common principles remain.

* Students are more likely to work independently if their design task is unique to them.
* Students are more likely to work independently if they have confidence in their own ability to complete the design task successfully.

To help students to complete a unique task independently, teachers could do the following.

* Set a common task for all students only when the task potentially has many different independent/control variables. For large class sizes, it can be difficult to ensure a wide enough range of different approaches.
* Set a limited selection of maybe two to four different design tasks in a circus of simultaneous experiments, during which only a small number of students address each task. Each task should have a range of potential independent variables to investigate, thereby allowing each student to make a unique choice. This arrangement means that limited equipment and materials can be shared out more evenly. The students can be rotated around the different tasks each time design is to be assessed.
* Set a wide-ranging list of design suggestions or encourage students to come up with their own ideas. This approach can generate truly individual work but it can be difficult for the teacher to organize and effectively supervise large classes.

If the teacher takes the approach of collecting and marking the designs prior to the action phase, then a wide-ranging list of tasks can be set, but students can then be teamed up for a common action phase in the event of materials being in short supply. (This does, however, weaken the sense of ownership a student has for their investigation and limits the effectiveness of the problem-solving learning opportunity.)

If a teacher is confronting the problem of many students simply reciting designs from web-based sources or lab manuals, it may be necessary to allocate supervised class time to the task of writing up designs.

To increase the students’ self-confidence in their ability to accomplish the task independently, it is important for the design-setting strategy to recognize that they need to have some familiarity with the concepts and techniques involved. Some suggested approaches are as follows.

* Set tasks that are an advance on prior work from pre-IB years or earlier in the IB course. However, it is inappropriate to set students essentially the same task as previously (for example, to ask students to investigate the effect of concentration on the rate of a given reaction when the students have already investigated the effect of temperature on that same reaction system). Similarly, teachers should avoid setting a task that is already covered completely in readily available literature such as the class’s laboratory manual (for example, to investigate the factors affecting the rate of reaction between sodium thiosulphate and hydrochloric acid). It is not uncommon to find whole classes responding in an identical manner to such a design task, and such an occurrence if left unaddressed will be acted upon by the moderator. In such cases it is better to restrict assessment to DCP and CE.
* Give students a practical session to familiarize themselves with the techniques required prior to the writing up of their design. They can use this session to try out materials, to develop a workable procedure, and to see if their proposed independent variable has any measurable effect. If the teacher takes the opportunity during this session to ask the students to explain their thinking behind what they are planning to do, then it is subsequently easier to ascertain whether the student has produced the final written design independently. Also, at this stage, students can be encouraged to think more deeply if they are considering undertaking an oversimplistic investigation.

Once a teacher has decided on a strategy for assessing design, acceptable instructions need to be given to the students. Normally this takes the form of a brief description of the general problem(s). Aspect 1 of the design criterion requires students to formulate for themselves the focused problem or research question, as well as to identify independent and dependent variables, and relevant controlled variables. It is essential that the teacher gives the students only an open-ended prompt, and the topic must allow for a variety of different approaches.

Most commonly, there are two types of appropriate teacher prompts.

* Firstly, the **dependent variable is given** by the teacher, and the student must select the independent variable as well as appreciate the controlled variables. An example here is when the teacher tells the student to investigate one factor that affects the output potential from an electrochemical cell.
* The second type of prompt is where **neither the dependent nor independent variables are given** but the **system to be investigated is identified**. An example of an open-ended teacher prompt would be “Investigate an aspect of an esterification reaction”.

Since it is necessary for students to identify an independent variable, that is, a variable whose value is changed in a controlled manner, it is **inappropriate** to set a task simply to measure a physical constant or quantity, for example, the molar mass of lighter fuel gas. If in response to an open-ended prompt a student decides to determine a chemical or physical constant, the measurement of which requires the identification and manipulation of an independent variable (such as an activation energy, where temperature must be manipulated between trials), then this is an acceptable quantitative extension of qualitative research. However, a teacher’s instruction **cannot** direct the student to this because such an instruction would effectively identify the independent variable for the student.

**Investigations suitable for design**

The possible dependent and independent variables are given in the suggestions below so as to aid teachers to plan and prepare for the assessment of design. These variables are **not** to be given to the students when setting the task, however.

**Investigations with many possible independent variables that are suitable for larger groups**

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| Investigate a factor affecting the rate of electroplating a metal. | |
| Dependent: | Quantity of metal deposited. |
| Independent: | Time, temperature, concentration of solution, identity of metal, size of electrode, voltage, current. |

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| Investigate the esterification reaction between a carboxylic acid and an alcohol. | |
| Dependent: | Quantity of ester, change in concentration of acid or alcohol, odour of ester product. |
| Independent: | Time elapsed, temperature, identity of acid, identity of alcohol, concentration of catalyst. |

Note: This can be an experiment to determine rate factors, the equilibrium constant or the nature of the organic products.

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| Investigate the effect of acid rain on building materials. | |
| Dependent: | Effect on material. |
| Independent: | Type of material, time of exposure, surface area exposed, method of measurement, temperature, nature of acid, concentration of acid, nature of exposure. |

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| Investigate a factor affecting the activity of a specified enzyme. | |
| Dependent: | Some measure of change of concentration of a reactant or product. |
| Independent: | Substrate concentration, pH, temperature, inhibitor concentration, sources of substrate. |

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| Investigate the factors influencing the voltage of an electrochemical cell. | |
| Dependent: | Voltage. |
| Independent: | Size of electrodes, distance between electrodes, nature of electrodes, nature of solution, concentration of solution, method of measurement, nature of ion transfer (salt bridge). |

Note: Any of the first five independent variables could be investigated.

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| Investigate the factors affecting retention in paper chromatography. | |
| Dependent: | Distance travelled by spot. |
| Independent: | Thickness of paper, nature of paper, identity and composition of eluting solvent, size of spot, concentration of solute, distance solvent travels, nature of solute, temperature. |

Note: Any of the first six independent variables could be manipulated.

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| Investigate testing the energy from liquid fuels. | |
| Dependent: | Temperature change of water. |
| Independent: | Construction of calorimeter (including nature of water container, amount and location of insulation, supply of oxygen), type of fuel, amount of fuel and/or time of burning, amount of water, distance of flame from calorimeter. |

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| Investigate factors influencing the solubility of salts. | |
| Dependent: | Mass of solute. |
| Independent: | Temperature, anion, cation, relation of charges of the ions, presence of other salt(s). |

Note: This investigation can address some very meaningful chemistry, but teachers should encourage students to avoid trivial investigations such as the effect of changing the volume of solvent. Also many students confuse “solubility” with “rate of dissolution”.

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| Investigate a factor affecting the viscosity of a liquid. | |
| Dependent: | Time taken to flow through a burette or pipette (or similar). |
| Independent: | Identity of liquid (for example, change within or between homologous series), composition of a binary liquid mixture, concentration of a dissolved solid in the liquid, molar mass of solute, temperature, thermal or mechanical history (for gels or emulsions). |

Note: Other variables, such as initial volume of liquid in burette, tap opening and so on, should be identified as controlled variables, but their manipulation as the independent variable is more appropriate to physics.

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| Investigate (quantitatively) a factor affecting the rate of a reaction. | |
| Dependent: | Change in concentration, volume of gas, intensity of colour, etc. |
| Independent: | Nature of reaction, structure of reactants (variation within an organic family of compounds), concentration of reagents, total volume, temperature, state of division of reactant (only for heterogeneous reaction), identity, quantity and subdivision of a heterogeneous catalyst, concentration of a homogeneous catalyst, stirrer speed (only for heterogeneous reaction) light intensity (only for photosensitive reactions). |

Note: This is a whole category of possible investigations. Some examples of possible reaction systems to be investigated are:

* the catalysed decomposition of hydrogen peroxide
* heterogeneous reactions of acids with carbonates or metals
* an esterification reaction
* hydrolysis reaction of halogenoalkanes
* halogenation of an alkane or cycloalkane.

The teacher may decide to specify the reaction system under investigation, although by leaving it open, a wider range of truly individual plans is possible. Most higher level students can be encouraged to undertake a quantitative investigation, which would be a more suitable application of their knowledge and skills.

**Investigations with fewer possible variables that are suitable for being part of a wide-ranging list of suggested topics**

Although all the following would be acceptable design investigations, they are too narrow to expect a large group of students each to find an independent aspect to study.

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| Investigate a factor affecting the amount of vitamin C in foods. | |
| Dependent: | Volume of titrant. |
| Independent: | Source of vitamin C, effects of different methods of food processing, effects of different methods of storage. |

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| Investigate the effect of one factor on the experimentally determined p*K*a of a weak acid. | |
| Dependent: | pH at half-equivalence point. |
| Independent: | Identity of acid (change within the homologous series), temperature, acid concentration (although this should not affect p*K*a, it does delineate the range over which the method of determination is applicable). |

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| Investigate the effect of one factor on the degree of evaporative cooling of a volatile liquid. | |
| Dependent: | Minimum temperature reached. |
| Independent: | Identity of liquid (for example, change within or between homologous series), composition of liquid (for solvent mixtures), concentration of a dissolved solid in the volatile liquid. |

Note: Other variables, such as volume of liquid used, ambient temperature, effect of a draught and so on, should be identified as controlled variables, but their manipulation as the independent variable is more appropriate to physics.

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| Investigate the effect of one chemistry-related factor on the deflection of the liquid flow in the presence of a charged rod. | |
| Dependent: | Angle of deflection. |
| Independent: | Identity of liquid (for example, change within or between homologous series), composition of liquid (for solvent mixtures), concentration of a dissolved solid in the volatile liquid. |

Note: Other variables, such as flow rate, amount of charging of rod and so on, should be identified as controlled variables, but their manipulation as independent variable is more appropriate to physics.

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| Investigate the effect of one factor on the colour produced by iron(III) and thiocyanate ions. | |
| Dependent: | Absorbance. |
| Independent: | Wavelength, concentration of Fe(III) ions, concentration of thiocyanate ions, identity of complex formed. |

Note: Students will probably vary one concentration or the other, while keeping other variables constant.

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| Investigate the effect of one factor on the experimentally determined molar mass of a volatile liquid. | |
| Dependent: | Volume of vapour. |
| Independent: | Identity of volatile liquid, temperature. |

Note: The normal method of determining the molar mass of a volatile liquid depends on the vapour being an ideal gas. Close to the normal boiling temperature, this assumption no longer holds.

In addition to the student work, samples submitted for moderation must include the instructions, written or oral, given to the student by the teacher. This vital information will be used by moderators to assess whether or not the experiment as given was suitable for assessing the criteria.